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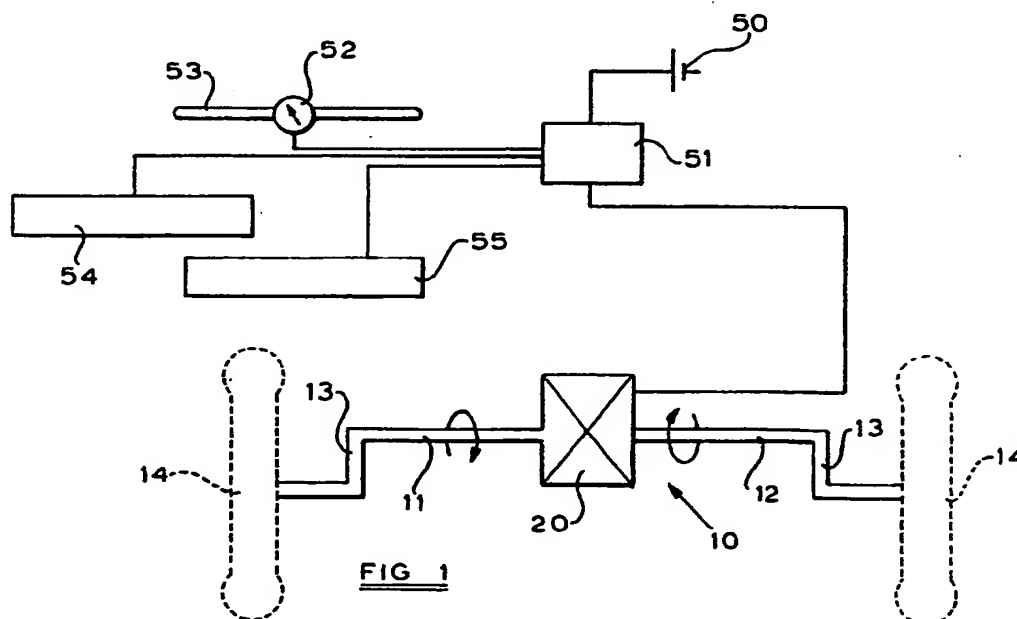
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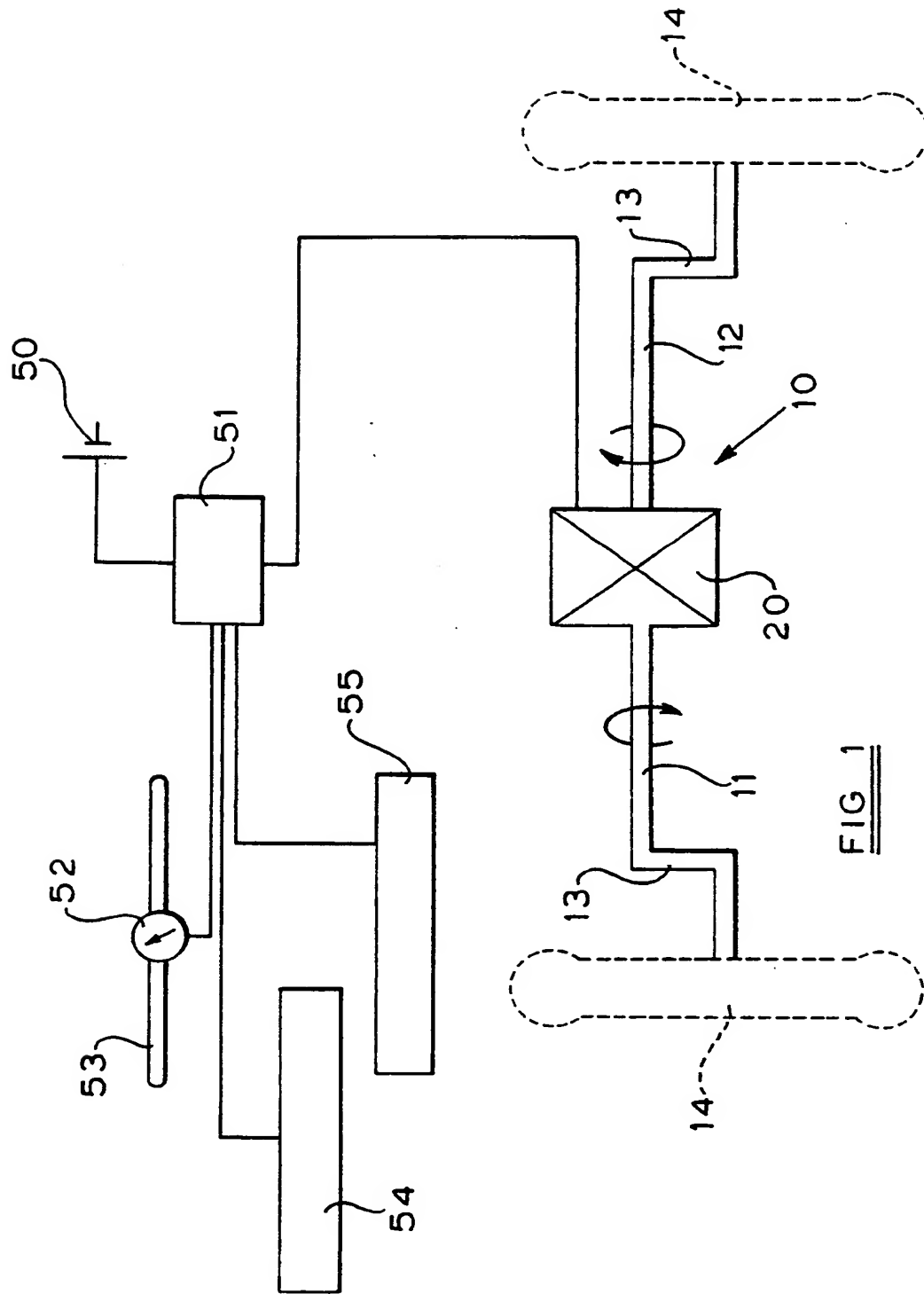
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## (54) Variable damping of an anti-roll bar

(57) An anti-roll bar 10 for a vehicle suspension has a pair of bar portions 11, 12 each connecting to one of a pair of wheels 14 on a common axle of a vehicle, the bar portions 11, 12 being interconnected by a fluid displacement device 20, the fluid displacement device 20 comprising a pair of chambers (40, 41 Fig. 4) arranged such that fluid will be displaced from one chamber (40) to the other (41) upon relative movement of the bar portions 11, 12; the fluid chambers (40, 41) being filled with an electrorheological or magnetorheological fluid and means being provided to apply an electric or magnetic field across the fluid to vary its viscosity.

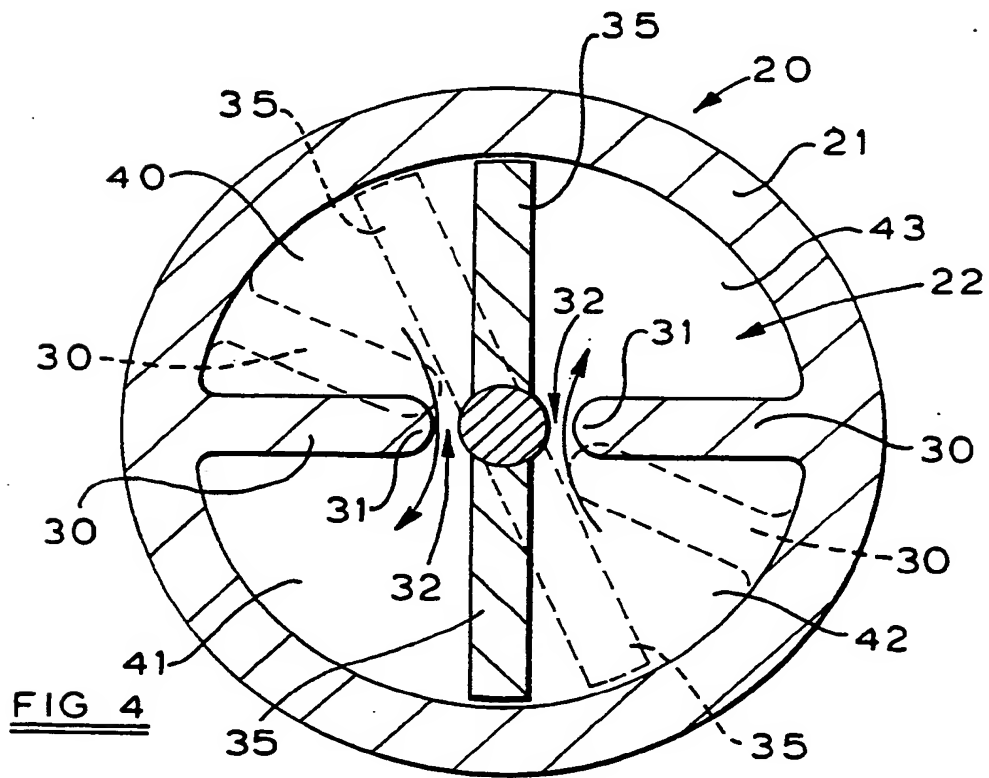
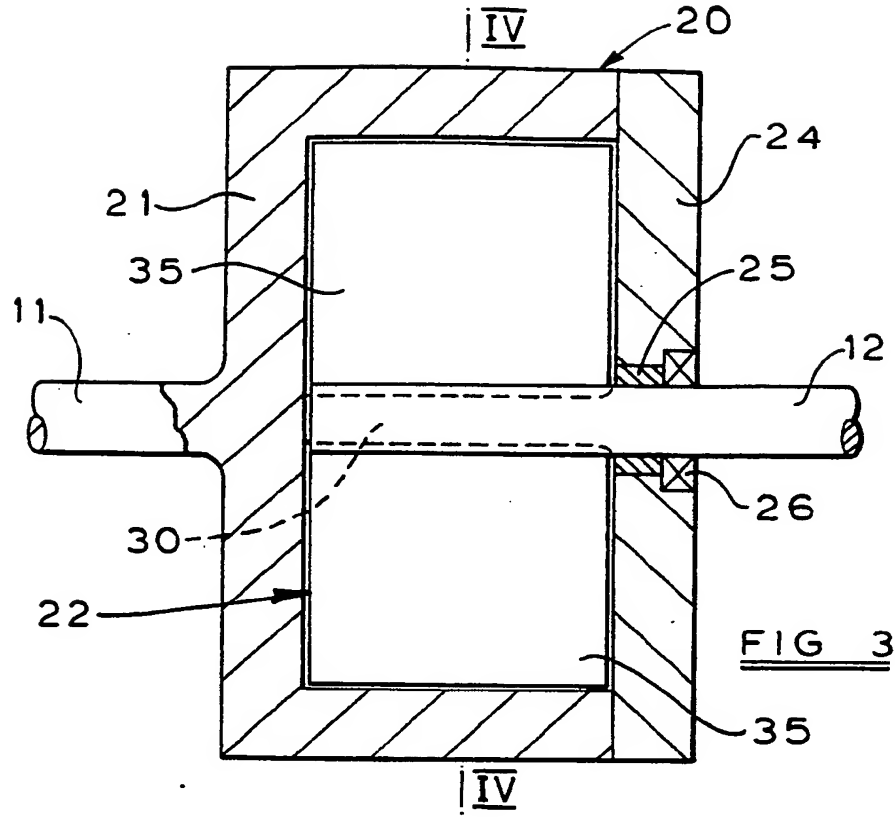


GB 2 275 661 A





3 / 3



VEHICLE SUSPENSION SYSTEMS

The present invention relates to vehicle suspension systems and in particular to vehicle suspension systems with adjustable roll stiffness.

5 In conventional road vehicles, it is normal practice to interconnect the suspensions of wheels on a common axle by means of an anti-roll bar, which works in torsion to restrict relative vertical movement of the wheels, thereby reducing the roll of the vehicle particularly on  
10 cornering. While an anti-roll bar of this type is particularly advantageous for high speed cornering manoeuvres, it will lead to stiffening of the suspension and hence give an unnecessarily harsh ride when the vehicle is travelling in a straight line. It is also  
15 undesirable to use anti-roll bars on vehicles which are to be used off road, where a high degree of independent compliance for each wheel is desirable.

The present invention provides a vehicle suspension system in which the wheels on a common axle of the  
20 vehicle are connected by an anti-roll bar, the stiffness of which may be adjusted to suit the driving conditions.

According to one aspect of the present invention, a vehicle suspension system includes an anti-roll bar having a first bar portion connected to a first wheel on  
25 a common axle of the vehicle and a second bar portion connected to a second wheel on the common axle, the first and second bar portions being connected to the respective wheels such that vertical movement of the wheels will apply torsional loads to the bar portions, the first and  
30 second bar portions being interconnected by a fluid displacement device, the first bar portion being connected to a first component of the fluid displacement device and the second bar portion being connected to a second component of the fluid displacement device, such

that relative movement of the first and second bar portions will cause relative movement of the first and second components, an electrorheological or magnetorheological fluid being disposed between said first and second components so that relative movement of the components will displace said fluid from one area to another, means being provided to apply an electric or magnetic field across the fluid to vary its viscosity.

With the device disclosed above, the viscosity of the electro- or magnetorheological fluid may be increased to increase the stiffness of the anti-roll bar or decreased to decrease the stiffness of the anti-roll bar.

According to a preferred embodiment of the present invention, the fluid when displaced from one area to another, flows through a restricted passage, the electric or magnetic field being applied across said passage so as to vary only the viscosity of fluid flowing through the passage. In this manner, the power consumption of the device may be minimised.

The viscosity of the fluid will vary with the strength of the electric or magnetic field applied. The stiffness of the anti-roll bar may thus be varied between; one extreme in which the components of the fluid displacement device will be effectively locked with respect to one another and the anti-roll bar acts as a conventional one-piece anti-roll bar; and the other extreme in which the components are free to move relative to one another with effectively no constraint within the limitations imposed by the permitted vertical movement of the wheels, when each of the wheels will be effectively independently compliant of the other.

The electric or magnetic field may be controlled in any suitable manner. However, preferably control means are

associated with the steering mechanism of the vehicle in order to stiffen the anti-roll bar when the vehicle is cornering and to reduce the stiffness when the vehicle is travelling in a straight line. Other means, for example  
5 wheel height sensors and lateral acceleration sensors may be included to refine the control mechanism. Means may also be provided to switch the system so that the wheels are independently compliant for off the road use.

10 An embodiment of the invention is now described by way of example only, with reference to the accompanying drawings, in which:-

Figure 1 illustrates an anti-roll bar of a suspension system in accordance with the present invention;

15 Figure 2 is an exploded isometric view of the fluid displacement device used in the anti-roll bar illustrated in Figure 1;

Figure 3 is a sectional view of the device illustrated in Figure 2; and

Figure 4 is a section along the line IV-IV of Figure 3.

20 As illustrated in the accompanying drawings, a vehicle suspension includes an anti-roll bar 10. The anti-roll bar 10 is formed from two bar portions 11, 12, each connected by a crank 13 to a wheel 14 on the common axle of the vehicle, in conventional manner. The bar portions  
25 11, 12 are secured to the sub-frame of the vehicle by means of rubber bushes (not shown) again in conventional manner.

The bar portions 11, 12 are coupled together at the ends thereof remote from the wheels 14, by means of a fluid  
30 displacement device 20. The fluid displacement device 20

comprises a housing 21 which defines a closed cylindrical chamber 22. The bar portion 11 is secured to the housing 21 so that its axis coincides with the axis of the cylindrical chamber 22.

5 The opposed end of the bar portion 12 extends through the end wall 24 of housing 21 into the cylindrical chamber 22, coaxially thereof. The bar portion 12 is electrically insulated from the housing 21 and is mounted in suitable bearing means 25. Sealing means 26 provides  
10 a fluid tight seal between the bar portion 12 and the end wall 24 of housing 21.

A housing 21 has a pair of diametrically opposed baffles 30 which extend longitudinally the full length of the chamber 22, the baffles 30 extending radially so that the  
15 inner ends 31 come into close proximity with the bar portion 12, to provide restricted passageways 32 therebetween.

Diametrically opposed radially extending vanes 35 are provided on the bar portion 12, within the chamber 22.  
20 The vanes 35 extend to within a close clearance with the circumferential wall and end walls of the cylindrical chamber 22.

The baffles 30 on housing 21 and the vanes 35 on bar portion 12 are arranged such that when the wheels 14 are  
25 at the same height, the vanes 35 will be disposed at 90° to the baffles 30, thereby dividing the cylindrical chamber 22 into four equal compartments 40, 41, 42 and 43. Compartments 40 and 41 and compartments 42 and 43 respectively, are interconnected via passageways 32.

30 The cylindrical chamber 22 is filled with an electrorheological fluid. The housing 21 and bar portion 12 are arranged to be connected to an electrical power



source 50 via an electronic control module 51. A  
rheostat 52 associated with the steering mechanism 53 of  
the vehicle, wheel height sensors 54 and a lateral  
accelerometer 55 provide input signals to the electronic  
control module 51.

In operation, as the wheels 14 of the vehicle move  
vertically relative to one another, the bar portions 11,  
12 and baffles 30 and vanes 35 connected thereto, rotate  
relative to one another. For example, on cornering one  
wheel will move upwardly relative to the vehicle while  
the other wheel moves downwardly. The anti-roll bar  
portions 11 and 12 will thus rotate in opposite  
directions as illustrated by the arrows in Figure 1.  
Rotation of the anti-roll bar portions 11 and 12 in this  
manner will cause the baffles 30 to rotate in one  
direction and the vanes 35 rotate in the other direction,  
as illustrated in broken line in Figure 3. As a result,  
the volumes of compartments 40 and 42 reduce while the  
volumes of compartments 41 and 43 increase. Fluid is  
consequently pumped from compartments 40 and 42 to  
compartments 41 and 43 respectively, through the  
passageways 32 as illustrated by the arrows in Figure 3.  
While no electric field is applied between the housing 21  
and bar portion 12, the fluid will be relatively free to  
flow through the passageways 32 and will present little  
resistance to the relative movement of the wheels 14.  
The wheels 14 will thus be effectively independently  
compliant.

When however an electric current is applied between the  
housing 21 and bar portion 12, the electric field  
produced between the housing 21 and bar portion 12 and  
vanes 35, will cause the viscosity of the  
electrorheological fluid to increase. The electric field  
will be concentrated between the ends 31 of baffles 30  
and the bar portion 12, thus increasing the viscosity of

the electrorheological fluid in the region of the passageways 32. The increase in viscosity of the fluid in this area will increase the resistance to flow of the fluid through the passageways 32, thereby resisting  
5 relative movement of the baffles 30 and vanes 35 and the bar portions 11 and 12 secured thereto. The stiffness of the anti-roll bar 10 may thus be increased in order to control the relative vertical movement of the wheels 14. The viscosity of the electrorheological fluid depends  
10 upon the strength of the electric field, and may be increased to such an extent that the bar portion 12 will be locked with respect to the housing 21, so that the anti-roll bar 10 will act as a conventional one-piece anti-roll bar.

15 When the electric current is applied between the housing 21 and bar portion 12, strong electric fields will also be produced between the opposed edges of the vanes 35 and the walls of the housing 21, thereby increasing the viscosity of the fluid in these regions and reducing the  
20 leakage of fluid therebetween.

The present invention will primarily be used to increase the roll stiffness of a vehicle on cornering, permitting the wheels to be substantially independently compliant when the vehicle is travelling in a straight line. When  
25 cornering, the electric field will be applied across the electrorheological fluid, when the wheels 14 are substantially level, thereby reducing the roll of the vehicle as it goes round the corner.

30 Manual switching means may be provided to override the electronic control module 51 so that the wheels may be maintained in their independently compliant mode during, for example, off road use. In such circumstances, means may also be provided to reconnect the electronic control module, if the various sensors detect that a high speed

cornering manoeuvre is being performed.

5 Various modifications may be made without departing from the invention. For example, rather than using an electrorheological fluid, a magnetorheological fluid may be used, the electronic control module controlling electromagnets to induce a magnetic field across the relatively rotatable components of the fluid displacement device.

10 While in the above embodiment, bar portion 12 extends through the end wall 24 of housing 21 into the cylindrical chamber 22, it will be appreciated that a separate rotor with vanes may be rotatably mounted in the chamber 22 and connected externally to the bar portion 12. Any number of baffles and vanes may be provided on  
15 the housing and rotor in order to divide the chamber 22 into a plurality of compartments.

Other forms of fluid displacement device in which relative movement of components of the device cause fluid to move from one area to another, may alternatively be  
20 used. For example, the fluid displacement device may be in the form of a positive displacement pump, one portion of the anti-roll bar being connected to the pump housing and the other to a pump rotor, the inlet and outlet of the pump being connected in close circuit through a  
25 restricted orifice, across which an electric or magnetic field may be applied.

The suspension according to the present invention may be used on the front and/or rear axle of the vehicle.

CLAIMS

1. A vehicle suspension including an anti-roll bar having a first bar portion connected to a first wheel on a common axle of the vehicle and a second bar portion connected to a second wheel on the common axle, the first and second bar portions being connected to the respective wheels such that vertical movement of the wheels will apply torsional loads to the bar portions, the first and second bar portions being interconnected by a fluid displacement device, the first bar portion being connected to a first component of the fluid displacement device and the second bar portion being connected to a second component of the fluid displacement device, such that relative movement of the first and second bar portions will cause relative movement of the first and second components, an electrorheological or magnetorheological fluid being disposed between said first and second components so that relative movement of the components will displace said fluid from one area to another, means being provided to apply an electric or magnetic field across the fluid to vary its viscosity.

2. A vehicle suspension system according to Claim 1 in which when displaced from one area to another, the fluid flows through a restricted passage, an electric or magnetic field being applied across said passage so as to vary the viscosity of the fluid flowing through the passage.

3. A vehicle suspension system according to Claim 1 or 2 in which the fluid displacement device comprises a housing defining a closed cylindrical chamber, a rotor being rotatably mounted within the chamber, the housing having at least one baffle extending longitudinally the full length of the chamber and radially into close proximity to the rotor to define a restricted passageway

therebetween, and the rotor having at least one vane extending longitudinally to a close clearance with the end walls defining the chamber and radially to close clearance with the circumferential wall defining the chamber, the baffle and vane dividing the chamber into two compartments, one bar portion being connected to the housing and the other bar portion being connected to the rotor, so that relative rotation of the bar portions will cause the housing and rotor to rotate relative to one another, and the baffle and vane move so that one chamber increases in volume while the other chamber decreases in volume forcing fluid to move from one chamber to the other through the restricted passageway.

4. A vehicle suspension system according to Claim 3 in which the housing has a pair of diametrically opposed baffles and the rotor has a pair of diametrically opposed vanes, the vanes being disposed at 90° to the baffles, when the wheels of the vehicle are level.

5. A vehicle suspension system according to any one of the preceding claims in which the first and second components of the fluid displacement device are electrically conducting and are insulated from one another, an electronic control module being provided to connect the components to a source of electric current, under appropriate conditions in order to provide an electric field therebetween.

6. A vehicle suspension system according to any one of Claims 1 to 4 in which an electromagnet is arranged to induce a magnetic field between the first and second components of the fluid displacement device, electromagnets being connected to an electronic control module by which it may be energised to produce a magnetic field between the components.

7. A vehicle suspension system according to Claim 5 or 6 in which the electronic control module acts to apply an electric or magnetic field across the components of the fluid displacement device, when the vehicle is undergoing a cornering manoeuvre.

5

8. A vehicle suspension system according to any one of the preceding claims in which sensing means on the steering mechanism, wheel height sensors and/or lateral acceleration sensors provide inputs to the electronic control module.

10

9. A vehicle suspension system according to any one of Claims 5 to 8 in which switching means is provided to disengage the fluid displacement device from the electronic control module in order to provide independent compliance of the wheels for off road use.

15

10. A vehicle suspension substantially as described herein, with reference to and as shown in Figures 1 to 3 of the accompanying drawings.

**Patents Act 1977****Examiner's report to the Comptroller under Section 17 - II -  
(The Search report)**Application number  
GB 9402808.1**Relevant Technical Fields**Search Examiner  
M D WALKER

(i) UK Cl (Ed.M) B7D (DCE, DSCD)

Date of completion of Search  
19 APRIL 1994

(ii) Int Cl (Ed.5) B60G 21/05, 21/055

**Databases (see below)**Documents considered relevant  
following a search in respect of  
Claims :-  
ALL(i) UK Patent Office collections of GB, EP, WO and US patent  
specifications.

(ii) ONLINE DATABASES WPI

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- A: Document indicating technological background and/or state of the art. &: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages	Relevant to claim(s)
A	EP 0183039 A1 (BOSCH) Whole document	1
A	US 4819772 (BOSCH) Whole document	1

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